

Analysis of medical needs during disasters caused by tropical cyclones: anticipated injury patterns

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SUMMARY

This paper is a summary of the data for describing the distribution of injuries among people affected by tropical cyclones that have occurred during the past 20 years. The most striking feature of the data gathered from a review of the epidemiologic literature on tropical cyclones is its lack of uniformity. The absence of an international classification and coding scheme for recording injuries sustained in cyclones also makes planning medical assistance difficult following future cyclones and hurricanes. We propose here a simple injury classification scheme comprising three components for categorizing injury data. Such a standardized disaster injury classification scheme, coupled with other types of information about injuries, will greatly aid relief officials in efficiently matching available resources to needs, in effectively managing health relief operations, and in developing strategies to prevent future cyclone-related morbidity and mortality.

Keywords: injuries, natural disaster, cyclone, hurricane, typhoon, disaster-epidemiology, disaster medicine

INTRODUCTION

A tropical cyclone is defined as a rotating wind system that whirls counterclockwise in the northern hemisphere, forms over tropical water, and has sustained wind speeds of at least 74 m.p.h. (45.9 km h^{-1}) (Longmire & Ten Eyck 1984). Known as hurricanes when they occur in the Atlantic or in the eastern or central North Pacific and typhoons in the western North Pacific, tropical cyclones are one of nature's most destructive phenomena, releasing in one day condensation energy equivalent to 400 one-megaton hydrogen bombs. Cyclones, hurricanes, and typhoons

have killed hundreds of thousands and injured millions of people during the last 20 years (Hagman 1984; Office of US Foreign Disaster Assistance 1992). An average of approximately 100 tropical cyclones occur each year, and each decade, three to four cyclones have truly calamitous effects. For example, in 1970, deaths resulting from a single tropical cyclone striking Bangladesh were estimated to exceed 250 000 (Sommer & Mosley 1972). More recently, the most costly natural disaster in United States history in terms of financial loss resulted from the impact of Hurricane Andrew in Florida and Louisiana in 1992. As population growth continues along vulnerable coastal areas, deaths and injuries resulting from tropical cyclones will increase (Gross 1991). Unless adequate means of evacuation and safe refuge are provided for residents in

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communities on barrier islands and other vulnerable coastal communities, future tropical cyclones may produce even greater loss of life and property.

THE NEED FOR ACCURATE DATA ON TROPICAL CYCLONE-RELATED INJURIES

The need for specific supplies and equipment such as blood, plasma, antibiotics, and cast material is rarely determined on an accurate basis during disasters so inappropriate items are often delivered to disaster sites (Autier *et al.* 1990). The scientific literature on tropical cyclones abounds with reports of inappropriate aid delivered to disaster-stricken communities and that hindered relief efforts (Dykewicz 1992). Such reports indicate that emergency health decisions are often based on insufficient, non-existent, or even false information which results in inappropriate, insufficient or unnecessary health care, wasted health resources and ineffective health measures (Seaman 1990). To determine the relief supplies, equipment, and personnel needed to respond effectively to disasters, we must obtain better epidemiologic knowledge about the causes of deaths and types of injuries associated with specific types of disasters (Armenian 1989; Binder & Sanderson 1987; Guha-Sapir & Lechat 1986). Effective emergency medical response to cyclonic storms depends on anticipating these different medical and health problems and delivering the appropriate interventions precisely when and where most needed (Pan American Health Organization 1987).

MORBIDITY AND MORTALITY TRENDS

Most of the death and destruction associated with tropical cyclones is caused by wind, flood-producing rains, and storm surges. Although high-velocity projectile debris can prove life-threatening to building occupants and any passers-by (Stubbs *et al.* 1989), the wind is not the biggest hurricane-related killer. Nine out of ten hurricane fatalities are caused by drownings associated with flooding and storm surges (Frazier 1979; French 1989; Orlowski 1988; Pan American Health Organization 1980).

In the early morning hours of Christmas Day 1974, Cyclone Tracy, with wind speeds exceeding 150 m.p.h., struck Darwin, Australia, a city of 45 000 people. Although 6000 homes were destroyed, the cyclone caused only 51 deaths (Pan American Health Organization 1981). To quantify and classify the nature of severe injuries, Gurd *et al.* (1975) reviewed the records of hospitalized residents of Darwin who sought treatment for cyclone-related injuries. Of 137 hospital admission diagnoses, roughly half were severe lacerations and the other half were blunt injuries caused when people were crushed, hit by missiles, or had fallen. Records indicated that some patients had both types of injury (Table 1). Minor injuries treated in the outpatient setting were not quantified and are not included in Table 1. However, most outpatient visits during the initial treatment phase were for lacerations from flying glass or other debris. A few persons were treated for fractures requiring closed reduction and for minor injuries. During the next few days, some patients were treated for infected wounds and a few relatively minor fractures were discovered. Many injuries were sustained after the cyclone and during the clean-up process. For example people suffered injuries to their feet from stepping on nails or broken glass.

To improve future hurricane preparedness and response, Standard (1979) evaluated injuries and other personal damage from Hurricane David, which struck the Dominican Republic in August 1979. Forty people died as a direct result of the hurricane; approximately 3000 people were treated for injuries, and most homes in the storm's path were severely damaged. More than 80% of the injuries were caused by stepping on building materials that were scattered about when the hurricane winds blew houses apart. A large proportion of the injuries were relatively minor. Of those who were injured, only about 70% sought medical treatment at hospitals and clinics. Self-treatment was the preferred method of wound care for about 15% of all injured people.

Almost two-thirds of injuries affected the lower limbs. Injuries to the upper limbs, particularly the hands, were next in frequency. Investigators further classified injuries into the following categories: cuts, nail wounds, blows and 'other'. There was an increased incidence of cuts (primarily from galvanized roofing sheets, loose building material, and nails) during and for several days afterward (Table 1). Despite efforts to ensure accurate reporting and data collection, this

Table 1. Type of tropical cyclone-related injury by study

Type of injury	Gurd (1975)	Philen (1992)	Standard (1979)	Longmire (1984)	Longmire (1988)	Roth (1991)
Abdominal injury (closed)						
Asphyxiation/fire/smoke		9 (20.5)				
Asphyxiation (trapped under tree)		1 (2.3)				
Traumatic amputation of feet	(0.7)					
Aspiration (gasoline)				3 (1.2)		
Assault, spouse				3 (1.2)		
Blow to body			39 (15.1)			
Burn				16 (6.5)		
Chain-saw injury		1 (2.3)		8 (3.2)	13 (10.0)	
Cut			109 (49.2)			
Drowning		8 (18.2)				
Electrocution		11 (25.0)				
Ear, nose, throat						20 (10.4)
Fracture (pelvis)						
Fracture (unspecified)						16 (8.3)
Heart attack		6 (13.6)				
Injury to head (major)	2 (1.5)					
Injury, spinal	7 (5.1)					
Injury, soft-tissue						131 (68.2)
Injury, others			24 (9.3)			
Laceration	60 (43.8)			167 (67.3)	103 (79.2)	
Paraplegia	5 (3.6)					
Sting(s)				15 (6.0)	14 (10.8)	
Trauma, blunt	50 (36.5)	8 (18.2)				
Wound, nail			82 (31.8)			
Wound, puncture				36 (14.5)		25 (13.0)
Wound (penetrating abdominal)	2 (1.5)					
Wound (penetrating chest)	1 (0.7)					
Unknown			4 (1.6)			
Total injuries	145 (100)	44 (100)	258 (100)	248 (100)	130 (100)	192 (100)

Values in parentheses are percentages.

broad classification of hurricane-related injury, the non-specific classification of injury type (e.g. cuts) and the lack of information on mechanism of injury makes it difficult to use such data to draw conclusions about appropriate surgical care needs after tropical cyclones.

Longmire and Ten Eyck studied morbidity associated with Hurricane Frederic (1984) and Hurricane Elena (1988) and were among the first to apply a systematic approach for quantifying disaster-related

injuries. In a retrospective review of records from one emergency department, injuries occurring one week prior to the hurricane and two weeks afterward were compared to a similar 3-week period during the previous year. The authors found a statistically significant increase in lacerations, puncture wounds, chain-saw injuries, burns, gasoline aspiration, gastrointestinal complaints, insect stings and spouse abuse in the two weeks after the hurricane (Table 1). The authors concluded that minor trauma that could be

treated in the outpatient setting created an urgent demand for primary care physicians and nurses skilled in managing minor surgical emergencies. In addition, although the number of chain-saw injuries was small, the time-consuming nature of treating such wounds increased significantly the demands placed on remaining emergency department personnel to treat people with other injuries. Results of neither study, however, gave any information on injury severity (e.g. neither use the Abbreviated Injury Scale or the Injury Severity Score).

In September 1989, Hurricane Hugo struck the islands of Puerto Rico and St Croix and the coast of South Carolina with tremendous force. Using local medical examiners' and coroners' data, Philen *et al.* (1992) investigated the circumstances of 44 Hurricane Hugo-related deaths that occurred in South Carolina and Puerto Rico (Table 1) (Centers for Disease Control 1989a). The causes and circumstances of all 44 hurricane-related deaths are shown in Table 1. Electrocutions accounted for 11 (25%) of all deaths; five of the seven electrocutions in Puerto Rico were occupationally related. Nine (20%) of the 44 deaths were related to house fires where candles were in use because of power outages. Eight (53%) of the 15 impact phase deaths were drownings that occurred during the storm surge, but these eight deaths accounted for only 18% of all hurricane-related deaths. Blunt trauma, either during or after the impact phase of the hurricane, killed eight people: four were crushed by collapsing mobile homes during the storm; one was crushed by timbers falling from a house; and three were fatally injured by falling trees. Six deaths (14%) in South Carolina were attributed to hurricane-related heart attacks. One death resulted from a chain-saw laceration of the neck, and one from asphyxiation secondary to chest compression caused by a falling tree. This study demonstrates that specific types of medical and health problems tend to occur at different points in time after a hurricane's impact. Thus, although a few severe injuries require immediate trauma care when and where the hurricane strikes, the majority of minor injuries occur during the clean-up period and may occur in a period of a few days to weeks after the event.

Hurricane Hugo also caused significant damage on the island of St Croix. Since all hospitals on the island were damaged by the hurricane's force, a temporary field hospital served as the only inpatient facility. Of the 192 people who were treated at this hospital, most

(68.2%) sustained soft-tissue injuries (Table 1) (Roth *et al.* 1991). Many of the soft-tissue injuries were puncture wounds caused when people stepped on nails during clean-up efforts. Field hospital personnel also sustained injuries including a ruptured biceps tendon, a fractured clavicle, and second-degree chemical burns from Clorox. Surgical procedures performed in the field hospital were also catalogued; most were simple wound closures. The types of analgesia used during these procedures included the full spectrum of medications and techniques used in a standard emergency department, from systemic drugs to local anaesthetics used for infiltration, and digital and haematoma blocks. Routine radiographs of the chest, neck and extremities were the radiological procedures most often performed.

The authors of the St Croix study also examined the types of drugs used at the field hospital. Interestingly, the most frequently prescribed outpatient medications were acetaminophen, ibuprofen, dicloxacillin and ampicillin; the pharmaceuticals most frequently administered to outpatients were for asthma (e.g. nebulized albuterol treatments) and diphtheria/tetanus vaccine for wounds; the most frequently used medications for hospitalized patients were parenteral cephalosporins and corticosteroids.

By recording both injury patterns and drug use, investigators in this study provide practical information that should prove invaluable in the future to emergency medical personnel responding to hurricanes. This study also serves as a model for future investigations to evaluate which medications are most needed by communities affected by hurricanes and other natural disasters (Autier *et al.* 1990).

Although fully equipped mobile hospitals and specialized surgical teams may arrive much too late at a hurricane-devastated area to be effective, the situation on St Croix after Hurricane Hugo demonstrates that such services may be useful in providing ongoing primary health care services to the community when all other health care facilities have been destroyed or severely damaged (Roth *et al.* 1991).

DISCUSSION

As the above studies have shown, casualties due to tropical cyclones vary greatly, from scratches, cuts, and abrasions that can be self or non-professionally treated (at so-called Red Cross training level) to a relatively small proportion of injuries requiring specialized

medical care. Unfortunately, the most striking feature of data from tropical cyclone epidemiologic literature is its variable quality and nature. Table 1 indicates the lack of consistency in classification of injuries. The lack of a standardized definition of injury and of a uniform classification scheme hinders detailed comparisons of studies performed for different cyclones and even studies performed in different areas affected by the same cyclone.

Information on hurricane-related mortality is available from many sources, including medical examiners' and coroners' reports, death certificates, the Red Cross, meteorological services, police and fire departments, and emergency medical services (Centers for Disease Control 1986, 1993; Patrick *et al.* 1992). However, these institutions or agencies use different methods and criteria for case selection (e.g. they each use different definitions of disaster-related injury) and no single source collects all the required information on deaths and injuries. Further, no universally accepted definition of a hurricane-related death exists. For example, in the Philen study, two coroners in South Carolina reported 'heart attacks' that occurred during the hurricane to be caused by hurricane-induced stress, but other coroners and medical examiners in other regions of the state did not consider any heart attacks to be hurricane-related no matter when they occurred and did not report them as such.

Therefore, to conduct a comprehensive analysis of the impacts disasters have on health, we must collect information from many sources and compare the sources systematically. Without a universally accepted definition of hurricane-related death, however, comparing death and injury data from these different sources may prove difficult if not impossible.

The absence of an international classification and coding scheme for injuries sustained during cyclones also makes it difficult to plan medical assistance packages. Classification of injuries varies from general (such as 'cuts') to very specific descriptions (i.e. 'bilateral foot amputation'). Most studies have only classified injuries as fatalities and non-fatalities (e.g. persons injured). Others have used uninformative terms such as minor, serious, or critical. There is a need to develop standardized definitions since there is a huge difference between minor contusions and life-threatening injuries requiring hospitalization. General injury descriptions such as 'cuts' are of little value as guides for determining which medications, medical

Table 2. Proposed classification scheme for injuries by anatomic site (component 1)

Head and neck	Hip and pelvis
Chest	Upper extremity
Abdomen	Lower extremity

supplies, and equipment are appropriate for tropical cyclone disasters. If the ultimate goal of epidemiologic studies of disasters is to improve the immediate decision-making process of those in charge of relief operations and to develop strategies to prevent future disaster-related morbidity and mortality, then we must implement a uniform method of describing disaster-related injuries.

An injury classification scheme ideally should consist of the following three distinct components to categorize injury data: (1) a simplified breakdown of anatomic sites of major injury in a person (not only the primary injury) (Table 2); (2) the data should indicate whether the patient requires inpatient hospitalization (if available) and those that can be managed safely as outpatients (Table 3). This would at least allow separation of minor from serious injuries; (3) finally, the data should indicate what type of medical personnel are most likely to be helpful (e.g. general surgeons, orthopaedic surgeons or neurosurgeons) (Table 4). With injury data categorized as just described, relief officials should be able to determine the medical personnel, supplies and equipment needed to provide appropriate care. The creation of an injury/illness classification scheme would also allow a plan to be developed for collecting appropriate data.

Despite the inherent difficulties in conducting studies of injuries following tropical cyclones, a number of studies have already shown that it is possible to collect valuable information that can be used for injury prevention (Centers for Disease Control 1993). The availability of injury surveillance questionnaires that are prepared before a disaster and can be modified quickly will assist in efficient data collection.

CONCLUSIONS

The advantage of a uniform reporting scheme for on-site data collection lies in its predictive value for

Table 3. Proposed classification scheme for injuries indicating the severity of the injury through skill level of provider required for treatment (component 2)

Injury severity code	Skill level of provider
	None; first-aid can be self-administered
	First-aid required but not necessary to see physician (e.g. Red Cross level training)
	Outpatient visit, but not necessary to see physician (e.g. no suturing, non-displaced fractures; care can be administered by emergency medical technician, paramedic, or nurse)
	Outpatient or emergency/accident department visit requiring physician care (e.g. suturing, more serious fractures)
	Hospitalized (e.g. in-patient observation, surgery or intensive care unit)
	Death
	Unknown

Table 4. Proposed classification scheme for injuries indicating type and nature of medical services required for treatment (component 3)

Code	Classification	Definition
MM	Medical	Patients having medical illness or disorder. Includes heart attacks, strokes, exacerbation of diabetes, high blood pressure, asthma, pneumonia, diarrhoea, etc.
MT	Toxicological	Patients with poisoning, chemical exposure, gas or smoke inhalation, etc.
ME	Environmental	Patients with drowning, hyperthermia, hypothermia
MP	Psychiatry	Patients requiring psychiatric care
SS	Surgery	Patients having conditions normally treated by surgery and not included in other categories
SO	Orthopaedic	Patients having conditions involving the musculoskeletal system for which orthopaedic treatment is indicated
SN	Neurosurgical	Patients having injuries to the brain and/or spinal cord
SB	Burns	Patients requiring treatment at a specialized burn unit. Includes thermal, chemical and radiation burns and electrocutions (e.g. lightning)
SG	OB/GYN	Female patients having gynaecological diseases or injuries, and patients who are pregnant or have any medical, surgical, or obstetric complication of pregnancy

profiling future needs. We propose here a simple injury classification scheme consisting of three components for categorizing injury data. Such a standardized disaster injury classification scheme, coupled with other types of information about injuries (e.g. injury rates and injury severity, types of medical services used, medications administered) will greatly aid relief officials in efficiently matching available resources to needs and in successfully managing future health relief operations following tropical cyclones (Noji 1992).

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